COMPARISONS OF ROUGH SURFACE BACKSCATTERING COEFFICIENTS FOR 2 DIMENSIONAL SCATTERING PROBLEMS USING NUMERICAL AND ANALYTICAL MODELS

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The NASA Soil Moisture Active/Passive (SMAP) Mission [1] will enable the mapping of soil moisture with unprecedented resolution. Soil moisture is an important parameter of the earth's water, energy and carbon cycle. The SMAP mission uses a combined active and passive sensor at 1.26 GHz and 1.41 GHz, respectively, and at an incidence angle of 40 degrees. The study of microwave interaction with soil surfaces is an important problem for both bare soil surfaces and vegetated surfaces.

Physical models for bare surface scattering include the analytical Small Perturbation Method (SPM), Integral Equation Model (IEM)[2], Advanced Integral Equation Model (AIEM) [3], Modified Advanced Integral Equation Model (MAIEM) [4] and Small Slope Approximation (SSA) [5], and the numerical models Method of Moments (MoM) [6] and Extended Boundary Condition Method (EBCM) [7]

A group of researchers from UW, OSU, UMichigan, UCSB and JPL has conducted a study to intercompare rough surface scattering models for SMAP applications. A 2D scarttering problem was used in the comparisons, because, for the 2D case, the height function $z = f(x)$ has a height varying in only one horizontal dimension so that the number of surface unknowns in numerical methods is more reasonable and there are several codes existing for these cases. An Gaussian random process model with an exponential correlation function is used for the surface description.

For the analytical methods, the SPM is applicable to scattering problems for rough surfaces having small slopes and RMS heights much smaller than incident wavelength. The IEM expresses tangential surface fields as a sum of the standard Kirchhoff surface field and a complementary surface field. The AIEM is a modification of IEM, based on the removal of a simplifying assumption in the spectral representation of Green's function. The MAIEM is modified version of AIEM with an improved calculation of Fresnel reflection coefficients through used of a "transition function". The SSA is applicable to surfaces having small slopes.

For numerical methods, the MOM uses surface integral equations constructed from Green's theorem. In order to convert these integral equations to matrix form, the surface fields are approximated as a set of basis functions with unknown amplitudes. The basis functions adopted include piecewise functions or rooftop functions for 2D simulation. The EBCM matches the extended boundary conditions derived from the extinction theorem at the test surfaces, which are away from the actual rough surface in each region, and a matrix system is constructed to retrieve the unknown electric and magnetic current sources at the actual surface.

University of Washington team members prepared MoM and AIEM predictions, while Ohio State University team members prepared MoM, IEM, and SSA results. University of Michigan team members prepared EBCM and MoM predictions, And University of California Santa Barbara team members provided MAIEM results. JPL team members provided testing parameters for the team. The calculations were conducted for the parameters of the SMAP mission: incidence angle 40 degrees, frequency 1.26 GHz, and for RMS heights from

1cm to 3cm. The ratio of the surface RMS height to correlation length was also varied from 1/20 to 1/5, and backscattering coefficients were computed as a function of the surface soil moisture.

UW team members' MoM is based on roof top basis function and a fast algorithm multi-level UV method [8]. OSU team members' MoM is based on pulse basis functions and a distinct fast algorithm, the Canonical Grid method[9]. Energy conservation and convergence tests were applied for UW's MoM. UW team members computed backscattering coefficients from a true exponential surface while OSU team members computed backscattering coefficients from a band limited exponential surface [10]-[11] with a 6mm cutoff length scale.

Comparisons of the results show that the MoM results agree with SPM and SSA when the roughness height is small. However, the differences become larger when the surface roughness increases. MoMs carried out by different groups are in good agreement with each other, and EBCM results are close to MoM results when the RMS height is small. For larger RMS height cases, the EBCM agrees with MoM results for HH polarization, but differs for VV. Also, we compared backscattering coefficients from band limited surfaces with true exponential surface.

Based on our comparisons, we conclude that none of the analytical models considered provide a complete match to the MoM over the range of statistics considered.

Key words: soil rough surface, active remote sensing, method of moments, extended boundary condition method, small perturbation method, integral equation method, small slope approximation

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